Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending September 5, 2020, are as follows:

NSTX-U RECOVERY (J. GALAYDA) AND RESEARCH (S. KAYE)

Recovery (J. Galayda):

Coils — A total of five coils (PF1B#1, PF1C#1, PFC#2, PF1A#1, and PF1A#2) have all been received at PPPL. Four coils passed low-power testing and PF1C#2 will be tested in the near term. PF1B#2 vacuum pressure impregnation (VPI) underwent curing and was released from the mold this week. In addition, spare coil winding was completed for the PF1C spare and the coil was prepped for brazing the flags. The PF1A spare was still being wound during the week.

Center Stack Casing (CSC) — The CSC was safely shipped to Turtle Creek and welding of the collar pieces began on each end. Upon completion early next week, the CSC will be returned back to Camden in early Sept. for final machining. In addition, vacuum testing of all of the spare bellows was successfully performed at PPPL and the bellows were trimmed and inspected so they could be sent to ORT/Holtec for installation.

IVPS — On-site activities to install power to the vacuum pump and perform mechanical installations of the vacuum system components will resume in late Sept.

Machine Core Structure (MCS) — Many fabrication activities continued at the three facilities currently making sling parts. Precision Boring in Michigan continued fabrication of the PF1A and PF1B capture and common flanges and the PF1C capping flanges for the sling supports (due for shipping in the next couple of weeks). In South Carolina, Carolina Fabricators continued production of PF1A sling parts. Also, G. J. Oliver added components to the machined PF1C supports and will ship the supports out for coating in the near term, with delivery slated for the end of the month. Additional procurement activities to award contracts for the remaining MCS components neared completion.

Personnel Safety System (PSS) — The AC Power Group began removal and packaging of the PSS breakers for shipment to ABB, Inc. for refurbishment. A total of 60 breakers will be refurbished and upgraded over the next three months.

PF Bus Supports — The design, analysis, and drawing efforts for coil flag position changes continued, along with finalization of drawings. Procurement activities continued in series towards final drawing updates.

South High Bay Labyrinth — BOA subcontractor 3BD Contracting replaced the door in the existing south high bay labyrinth. Work on the new labyrinth will conclude next week with the installation of the sprinkler system.

PFC Outboard Divertor Tiles 1 and 2 Modification Peer Review — A peer review was held Sept. 2 to review the geometry inconsistency between the CAD model and the final tile design. In a recent review of plasma-facing component (PFC) CAD drawings, it was found that the newer version from Apr. 2020 of the outboard divertor 1/2 (OBD12) tile front surface has a tile castellation of a much smaller angle of fish-scaling than what is needed. This caused concern that it may not shade the adjacent gap to avoid high leading-edge heating. To ensure that the project-defined key performance parameters (KPPs) can be achieved for machine operations, the outboard divertor 1/2 (OBD12) tile front surface will need to be optimized with a fish-scaling castellation consistent with what was presented at the PFC final design review held in Oct. 2018. The peer review was held to verify the assumptions and geometric shadowing used in the tile FDR analysis is correct and to confirm that design drawings are updated to correct the CAD geometry inconsistency.

Research (S. Kaye):

S. Kaye gave a webinar entitled, "The NSTX-U Research Program" to the ENN Energy Research Institute in China on Aug. 31. The webinar was attended by over 20 ENN and other researchers. The presentation focused on the motivation for ST research, and specifically how the NSTX-U mission fits into the U.S. domestic and international fusion energy development program. The motivating physics and research goals for the NSTX-U mission elements were presented during the webinar.

Progress in the Heat Flux Engineering Analysis Toolkit (HEAT), developed by Oak Ridge National Laboratory and the University of Tennessee-Knoxville, was presented to the NSTX-U team on Aug. 31. HEAT is designed to connect fully featured 3-D CAD models for plasma-facing components to physics-based predictions of time-evolving surface heat flux that use experimental and modeled equilibria, and solve the time-dependent heat diffusion equation in the material to predict surface temperature rises. It can be used in the design process to help optimize PFC shaping, as demonstrated by its recent use by the NSTX-U Recovery Project to adjust OBD12 fish-scaling, and is intended for use in pre-shot estimation and post-shot confirmation of surface temperatures during operations. A first release of the code is being finalized, and capabilities and quantitative results for NSTX-U PFCs developed by the recovery project were summarized. Static, high-flux expansion equilibria were shown to be limited to ~2.5 sec at full power without divertor dissipation, while a sweeping scenario was shown that needed to push beyond 5 Hz at high power to avoid sublimation limits.

A paper titled, "Simulating pitch angle scattering using an explicitly solvable energy conserving algorithm," by X. Zhang, Y. Fu, and H. Qin was published on Sept. 1 in *Physical Review E:* https://doi.org/10.1103/PhysRevE.102.033302. It is shown that the standard Euler-Maruyama algorithm for stochastic differential equations (SDEs) does not converge for the SDE describing the pitch angle scattering. As a remedy, an explicitly solvable energy-conserving algorithm is developed. Its consistency is theoretically and numerically proven. This study demonstrates that, for applications in plasma physics, the structure-preserving property is even more important for SDE algorithms than it is for deterministic differential equation algorithms.

An NSTX-U/ST-40 ECH collaboration Zoom meeting was held on Sept. 2 by researchers from Tokamak Energy/ST-40, PPPL, and the University of Wisconsin. NSTX-U researchers M. Ono and N. Bertelli presented a result of the ST-40 start-up and ramp-up scenarios for the low-field-side 140 GHz O-mode ECH/ECCD. O-mode and X-mode analyses are both necessary since a mixture of O-mode and X-mode is usually excited in the actual start-up experiments. The analyses show that the X-mode ECH/ECCD performance is significantly (by an order of magnitude) better than the O-mode for both heating and current drive efficiencies, which motivates to maximize the polarization to launch predominantly X-mode in the experiment.

ITER PROJECTS (H. NEILSON)

Project Control (E. Nassar):

The Laboratory's ITER team submitted an updated Estimate at Completion (EAC) for the preliminary and final design of all 11 Diagnostics sub-projects and for fabrication of first plasma equipment. In addition to task-based estimates by project leads, the team analyzed the uncertainty range in its estimates, relying on DOE classification guidelines and standard statistical analysis methods. While the projects are in general still at a relatively low level of design maturity, the team's methodology in developing an estimate was judged by independent reviewers to be appropriate. The Laboratory's submission this week supports a U.S. ITER initiative to update its estimate for completion of all design and delivery of all first plasma equipment.

The Laboratory's ITER leadership team met with members of the Princeton Site Office (PSO) to discuss the ITER project and PPPL's responsibilities in particular. Subcontract procurement was highlighted as an area where the Laboratory and PSO can partner in advancing the project objectives in a compliant manner.

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ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson)

Research:

A physics validation review (PVR) for an upper main-chamber Ly-alpha measurement was presented by F. Laggner representing the collaboration between PPPL and MIT that delivered the existing lower main-chamber Ly-alpha diagnostic (LLAMA). The PVR aims to deliver a similar capability for the upper half of the DIII-D vessel, which houses more closed DIII-D divertors.

F. Laggner delivered an online seminar talk in the FusionEPtalks series, a student-led seminar of the European Master in Fusion Science and Engineering program. In the seminar, entitled "Diagnosing Fusion Plasmas: From Concept to Reality," Laggner described the path to new understanding enabled by new measurements capabilities in magnetic fusion experiments, using the DIII-D Ly-alpha diagnostic (LLAMA) as an example.

International PMI (R. Maingi & A. Diallo):

The paper, "ELM suppression by boron powder injection and comparison with lithium powder injection on EAST," by R. Maingi, J. Hu, Z. Sun, et al. was accepted for publication in the *Journal of Fusion Energy*. The paper describes EAST experiments in which boron and lithium powder were injected during plasma discharges to eliminate ELMs. The minimum flow rate to eliminate ELMs was shown to increase with auxiliary heating powder. A direct comparison of born powder and lithium powder to eliminate ELMs was presented.

A periodic meeting of the domestic liquid-metal plasma-facing component design activity was conducted. In addition to round table technical presentations, plans were made for a year-end report of technical activities.

International JET/EU (M. Podestà, F. Poli):

A paper titled, "Improvements to the Faraday cup fast ion loss detector and magnetohydrodynamic induced fast ion loss measurements in Joint European Torus plasmas," by P. Bonofiglo et al. has been published online in *Review of Scientific Instruments*: https://aip.scitation.org/doi/10.1063/5.0014278. The paper describes recent upgrades to the JET Faraday Cup array, including improved electronic hardware and detector design in preparation of the upcoming DT-campaign. Initial tests of 200 kHz digitizers, as opposed to the original 5 kHz digitizers, have already provided

enhanced analysis techniques and direct measurements of coherent fast ion losses caused by MHD activity for kink modes, fishbone modes, edge-localized modes, and sawteeth. The full upgrade of the acquisition enables detection of alpha particle losses due to a variety of resonant fast ion transport mechanisms to be used in future DT-experiments and modeling efforts.

International EAST (F. Poli):

W. Choi has successfully completed the validation of LHCD models in TRANSP against experiments on EAST to study the synergy between sources with different frequencies. Critical for this effort has been a combined analysis from multiple diagnostics that Choi has taken the lead on, working with the EAST team. PPPL is looking into making this approach more automated and routinely applied to the analysis of EAST discharges.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates):

A. LeViness, a third-year Ph.D. student working under D. Gates, has applied the method of single-surface quasi-axisymmetry optimization, as seen in the work of S. Henneberg of IPP Greifswald, to the LI383 stellarator equilibrium in order to find equilibria with better QA and improved fast-particle confinement. This work is ongoing and will be presented as a poster at this year's APS-DPP meeting.

C. Zhu is going to give an invited talk at the AAPPS-DPP 2020 e-conference Oct. 26-31. He will make a presentation entitled, “Design of a permanent magnet stellarator.” In the presentation, he will summarize the effort that takes place in the lab to design a permanent magnet quasi-axisymmetric stellarator. The results obtained by the new code, FAMUS, for a half-Tesla NCSX-like configuration have led to a new $4.3 million project funded by DOE ARPA-E.

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard):

The Office of Communications posted two press releases to the PPPL website. The first reports on two new public-private collaborations awarded to the Laboratory by the DOE’s Innovation Network for Fusion Energy program, which A. Diallo co-directs. The second reports on research by I. Ochs and N. Fisch revealing that electrical currents can form in ways not known before. Both stories were also posted to the *Newswise* and *EurekAlert* press release distribution services.

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DIRECTOR'S OFFICE (S. COWLEY)

Laboratory leadership has been communicating ongoing updates to staff regarding the COVID-19 virus and PPPL.

J. Menard and S. Cowley participated in the virtual meeting of the National Academy of Sciences (NAS) Committee titled, "Key Goals and Innovations Needed for a U.S. Fusion Pilot Plant" on Sept 2.

S. Cowley participated in the virtual TDoTP (Turbulent Dynamics of Tokamak Plasmas) External Advisory Board (Department of Physics/University of York) Sept. 2-3. The TDoTP external advisory board is a research collaboration between the Universities of Oxford, Strathclyde, Warwick and York in partnership with Culham Centre for Fusion Energy and funded by the Engineering and Physical Sciences Research Council. The main aim of the meeting is to advance scientific understanding of plasma turbulence.

S. Cowley participated in the virtual NLDC (National Laboratory Directors Council) Fall Retreat on Sept. 2-3.

M. Zarnstorff participated in the virtual Exascale Applications Meeting on Sept. 4.

This report is also available on the following web site:

http://www.pppl.gov/publication-type/weekly-highlights